FREDERICK MCCOY AND THE SILURIAN SYSTEM

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McCann, Doug & Archbold, N. W., 2005. Frederick McCoy and the Silurian System. *Proceedings of the Royal Society of Victoria* 117(2): 151–173. ISSN 0035-9211.

The foundation of the Silurian system in 1835 by Roderick Murchison and the subsequent publication in 1839 of his monumental work *The Silurian System* (along with its accompanying map) is generally recognised as a landmark in the progress of global stratigraphy. The physical structure, composition, fossil content and stratigraphical order of these previously obscure Lower Palaeozoic strata were now made manifest and thus available for correlation within Great Britain and Continental Europe and, eventually, worldwide. Murchison's Silurian system was rapidly accepted by the majority of geologists as the major period of the Lower Palaeozoic. Murchison's triumph, however, brought him into conflict with his former friend and collaborator Adam Sedgwick who accused him of overextending the lower boundary of the Silurian and encroaching on geological territory which was rightly part of the Cambrian system. In 1835 Sedgwick had proposed the Cambrian system directly following Murchison's declaration of the Silurian system. The Cambrian-Silurian debate escalated into one of the longest running and most bitter disputes in 19th Century geology.

Irish-born Frederick McCoy, who published *The Silurian fossils of Ireland* in 1846, later became embroiled in the Cambrian-Silurian debate while working as Sedgwick's palaeontological assistant. It was McCoy who established that Sedgwick's Cambrian system contained its own distinct fossil assemblages and could justifiably be separated out from Murchison's all encompassing Silurian. Following his emigration to Australia in 1854 McCoy recognised the Silurian and Cambrian locally, and then went on to validate the presence of other major European systems, such as the Cretaceous and the Devonian, along the length of the geological column. McCoy was therefore the first to confirm unequivocally that the geological column was a coherent global entity.

Keywords: Lower Palaeozoic, Silurian, Stratigraphy, Cambrian

IN 1839 Roderick Murchison (1792–1871) published his monumental work *The Silurian System*, one of the most significant geological publications of the 19th Century. As well as launching the Silurian system as a pivotal stratigraphical unit in the Palaeozoic Era it helped confirm Murchison's status as one of the world's most pre-eminent geologists. Murchison's global influence in geology is difficult to overestimate. He was the founder of the Silurian system, founder of the Permian system and with Adam Sedgwick co-founder of the Devonian system. His Silurian system rapidly received international acceptance. Frederick McCoy (c. 1823–1899: Figs.1, 2 herein) was a young man when Murchison published *The Silurian System* but as he gained experience and insight as a novice palaeontologist he was suitably awed by Murchison's achievement. Under Adam Sedgwick's tutelage he later came to question some of Murchison's interpretations. McCoy, in fact, made the vital breakthrough which led to a reconsideration of the evidence of just where the lower boundary of the Silurian period lay and paved the way for the recognition of a legitimate and distinct Cambrian period as Sedgwick had long advocated. This key insight was a first step in an eventual resolution of the debate. McCoy went on to play a leading role in the correlation of the stratigraphical periods in Australia, including the Silurian, with corresponding European and North American units.

The Silurian period as defined in the early 21st century is a greatly reduced entity in comparison with that delineated by Murchison in the mid 19th century. It is now the shortest period in the Palaeozoic Era, covering a span of some 28 million years (International Commission on Stratigraphy 2004, from Gradstein et al. 2004) — about half that of the other major periods which are all in the vicinity of about 50 million years duration. At its zenith in the 1840s Murchison's Silurian system included everything below the Devonian down to the top of the basement rocks of the 'Azoic' (or in modern terms the Precambrian) — amounting to about 150 million years duration or about half of the Palaeozoic Era. In retrospect, Murchison's fear that if he compromised

Fig. 1. Lithograph of Frederiek MeCoy by Frederiek Sehoenfeldt, signed by Frederick MeCoy; from a series entitled 'Notable Men of our time'. Published by Hamel and Co., e. 1859. La Trobe Pieture Collection, State Library of Vietoria.

on the extent and boundaries of his Silurian system his hard won geological territory would be in grave danger of becoming "attenuated" proved to be well founded. Within a few years of Murchison's death the suggestion was made by Charles Lapworth that a new period, the Ordovician, be substituted in the place of his Lower Silurian (Lapworth 1879). This proposal gradually gained international acceptance and Murchison's once vast Silurian was whittled down to its present size.

The establishment of the Silurian system by Murchison and of the broader ordering of the stratigraphical rock sequence as a whole was one of the major achievements within geology in the 19th century. Murchison's demarcation of the Silurian rocks was a milestone in the development of stratigraphical palaeontology especially in its application as an indispensable aid to geological mapping. Some notion of the rapidity with which the Silurian system was adopted throughout Europe is indicated by its inclusion into Grigorii Petrovich Helmersen's Geological Map of European Russia in 1841 (Hecker 1987). Murchison clashed with Sedgwick on, among other things, the issue of fossils versus lithology as being satisfactory and sufficient indicators of a geological period. Frederick McCoy, who was just beginning to establish himself as a capable palaeontologist at this juncture in the late 1830s, later became involved in the debate and provided further evidence that fossils, if available, can indeed be definitive indices for the demarcation of the geological time scale, just as Murchison was arguing. Nevertheless, it was Sedgwick rather than Murchison who benefited most from McCoy's palaeontological work.

McCoy's early career in Ireland

Little is known of Frederick McCoy's early education (Darragh 2001: 160). There is also some uncertainty about his exact date of birth; however, he later testified several times that he developed an interest in natural history at a very young age. He was only a young teenager when he published his first paper — on ornithology, for which he retained a life-long interest. The paper was titled 'Remarks on Mr Eyton's arrangement of the Gulls' (McCoy 1838), published in the *Magazine of Natural History*. Typically for McCoy his initial paper addressed some of the finer points of biological classification and nomenclature. In 1839 he joined the Geological Society of Dublin and began to specialise in the study of fossils. He was appointed assistant to Dr John Scouler one of the Society's secretaries and helped arrange the fossil collections in the Society's Museum (Griffith 1841). As Darragh (2001: 160) notes, Scouler, who was a noted naturalist and Professor of geology, zoology and palaeontology at the Royal Dublin Society, must have been an important early influence on McCoy. It was also in 1839 that McCoy published his first paper on fossils. He described a Carboniferous ostracod and named it after his mentor *Entomoconchus scouleri*.

His work for the Geological Society of Dublin required him to curate and arrange the fossil collections of the Museum. In 1841 he arranged for sale the Henry Charles Sirr collection of shells and fossils as well as curating the collections of the Geological Society of Dublin and the Royal Dublin Society. In addition, by this time McCoy was also deeply involved in palaeontological work for Richard Griffith (1784–1878) who was primarily responsible for the production of the first complete geological map of Ireland. McCoy was commissioned by Griffith to work on the extensive Carboniferous Limestone fossil collections made by Griffith and his staff of the Boundary Survey of Ireland. Griffith needed these fossil determinations to establish the relative ages of sedimentary strata for the compilation of his Geological Map of Ireland. McCoy described some four hundred and fifty new species of fossil organisms. After some delay the results were published in a monograph in 1844 as *A Synopsis of the Characters of the Carboniferous Limestone Fossils of Ireland*.

An examination of the list of the fossil descriptions included in McCoy's book on the Carboniferous indicates the scope of his abilities at a relatively young age (Archbold 2001). Fossil phyla covered included (in modern taxonomic terms) Cephalopoda, Gastropoda, Bivalvia, Conulata, Brachiopoda, Trilobita, Ostracoda, Annelida, Echinodermata, Coelenterata and Bryozoa. Obvious also is McCoy's talent as a natural history artist. Archbold judges that "his illustrations of new species were also of exceptional quality for their time". They were drawn as realistically as possible, usually showing the imperfections of the specimens and less simplified than, say, Phillips (1836, 1841) or less idealised than, say, de Koninck (1842) or those of other comparable authors of the time. It is significant that von Zittel (1901: 451) in his *History of Geology and Palaeontology* remarks that the publications of de Koninck, Phillips and McCoy

were 'still the basis of all European research on the faunas of the Carboniferous limestone'. McCoy's works are still regarded as being classic contributions to palaeontology (as, for example, his contributions on the study of Palaeozoic corals (see Ivanovskii 1973)).

Further work for Griffith carried out by McCoy resulted in a second book *A Synopsis of the Silurian Fossils of Ireland* published in 1846. Seventy new species were included and as with the previous book about 12 phyla were described in total. As Archbold (2001) notes, McCoy possessed an exceptional knowledge of the earlier and contemporary palaeontological literature of both British and continental European workers. Adam Sedgwick, who first met McCoy while on a visit to Dublin in 1841, later said of McCoy that "no one of my friends...has so large an historical knowledge of foreign works on Palaeontology".

During his work on the Irish Silurian McCoy became thoroughly acquainted with Roderick Murchison's research and thinking. Of necessity, one of the main reference works McCoy consulted was Murchison's authoritative *Silurian System*. Griffith had delayed publication of the *Silurian Fossils of Ireland* in the hope that he would have the opportunity to write a description of the geology of the collecting localities. Unfortunately this expectation was not realised and in the meantime Murchison and colleagues published his second major opus *Geology of Russia* which included details of the Silurian geology and fossils of Russia, the latter largely by de Verneuil. This forced Griffith to instruct McCoy to revise his already completed fossil determinations. Griffith explained this situation in his introduction (or 'Notice') at the beginning of the *Silurian Fossils of Ireland*:

> "The following Synopsis of Fossils collected by me from the several Silurian districts of Ireland, was completed by Mr M'Coy in the month of May, 1845, but its publication was delayed, in the expectation that, in the intervals of public duty, I should have had the leisure to prepare a Memoir descriptive of the Geology of the several localities, and thus render the work more perfect and useful. Unfortunately, I have been disappointed in this expectation, and, in consequence, have determined to print it in its present form. In the interval which has elapsed between the completion of the Synopsis and the present time, Sir Roderick Murchison's splendid and admirable Work on the Geology of Russia has appeared, and with it the labours of M. de Verneuil and Count Keyserling on the Palaeozoic Fossils of Russia, &c., many of which occur in the Irish deposits. At my request Mr M'Coy has revised his Manuscript, and introduced the improvements in nomenclature proposed and adopted by those distinguished Palaeontologists" (Griffith, in McCoy, 1846).

In 1845 the Geological Survey of Ireland was established under Captain Henry James as the Irish Local Director. James was accountable to Henry De la Beche who as Director General of the Geological Survey of England and Ireland issued a set of instructions on the type of observations that were to be made in the field (Herries Davies 1983: 127). McCoy was the first field-surveyor appointed to the Irish Survey. James hoped to utilise McCoy's already significant palaeontological experience for the determination of the fossils collected by the Survey's Irish staff but De la Beche insisted that they should be sent to London for examination by the palaeontologist Edward Forbes (Darragh 1992). In lieu of doing fossil determinations McCoy instead was sent out into the field and was responsible for the production of some of the Irish Survey's very first maps. Many years later in 1889 giving evidence to a Royal Commission on Coal for the Victorian government, McCoy recalled:

> "Yes, I was a member of the Imperial Geological Survey, and made in the field the geological maps of several counties, entirely by myself, for the British Government, according to the methods of the Imperial Geological Survey, which is considered the best in existence; and then, from a very early period of my rather long life, I have devoted myself to a branch of geology [i.e., Palaeontology] which I found people had not sufficiently acquainted themselves with...and before coming to this colony I had already established myself as an authority upon that branch of geology...." (McCoy 1891)

It might seem from the above quotation that during the early period referred to McCoy was happily engaged in field-work and mapping activities but this was far from the case. This was a troubled period for McCoy. Unfortunately for McCoy, Henry James who was pleased with McCoy's work resigned in 1846, and he was replaced by Thomas Oldham (1816–1878) with whom McCoy had previously quarrelled at meetings of the Geological Society of Dublin. Oldham had criticised McCoy's work on the fossils of the

Carboniferous and McCoy had vigorously defended himself. Aware of this antagonism, James, as one of his last actions as Local Director wrote to De la Beche stating that '...it is clear that Oldham's appointment as Local Director, makes McCoy's position particularly unfortunate, and I should think it would be advisable to remove him to England.' De la Beche, however, for whatever reason chose to ignore James' advice.

Oldham, who later moved on to a distinguished career as head of the Geological Survey of India, was soon chastising McCoy for numerous errors, omissions and careless work. This, incidentally, was not the first time McCoy had been accused of shoddy work. In 1842 he had lost his position at the Geological Society of Dublin because of alleged neglect of his curatorial duties. At that time he was deeply involved with his work for Richard Griffith and this may have left him open for criticism (Darragh 2001: 161). Oldham had been McCoy's successor as curator of the Geological Society of Dublin. Under Oldham's supervision at the Irish Survey, McCoy's position became increasingly untenable. Following James' departure McCoy attempted to find alternative employment and applied for several jobs but was not successful.

It is difficult from this distance in time to judge the relative merits of the accusations by Oldham against McCoy but in making an assessment several points need to be considered. Firstly, there was undeniably considerable hostility between them which probably coloured the issues. Secondly, as Herries Davies (1983: 142) points out, 'One of McCoy's problems in 1846 may have been that he was inadequately briefed as the duties of a field-geologist. De la Beche's *Instructions* of May 1845 had been singularly unhelpful in this respect'. This problem was compounded by the fact that James himself seemed to have little idea of what was necessary. Herries Davies (1995: 34) comments that, 'One must, nevertheless, have some sympathy with M'Coy. Neither he nor any other of the Survey's officers, would seem to have received any clear instruction from James as to the nature of their duties.' Thirdly, James had hired McCoy hoping to draw upon his palaeontological skills. McCoy had similar expectations himself. He was much more oriented towards the identification and classification of fossils than field mapping *per se*. Nevertheless, despite McCoy's difficulties during this period they seem to have had little negative impact on his future career.

McCoy at Cambridge University

In an attempt to extricate himself from his predicament at the Geological Survey of Ireland, McCoy wrote to Adam Sedgwick (1785–1873) the Woodwardian Professor of Geology at Cambridge University, who at that time was in need of a palaeontologist. Sedgwick was impressed with McCoy, later stating that, '...when I first saw him (in 1841) he had nearly completed his volume on the Carboniferous Fossils of Ireland. His Irish works put him in the front rank of British palaeontologists' (Sedgwick and McCoy 1855: xvi). In November 1846 Sedgwick wrote back to McCoy and offered him employment. He was invited to arrange the collections in the Woodwardian Museum at Cambridge. Sedgwick was confident that McCoy would be equal to the task. Commenting on his first interactions with McCoy, Sedgwick recalled that,

> "When my friend formed his first engagement with this University, he came amongst us young indeed in look; but, even then, a veteran in Palaeontology. He was well trained and ready for the task he had undertaken; and far better stored with a knowledge of the foreign standard works on Palaeontology than any man with whom I had before conversed" (Sedgwick 1855: xvi).

The Woodwardian Museum housed a large collection that was originally established by a bequest by John Woodward (1665–1728) more than a century earlier. The original collection had been added to considerably over the ensuing years, including many specimens collected by Sedgwick and his students over three decades. Sedgwick also supplemented and expanded the collection by the purchase of other geological collections and selected individual specimens to develop one of the finest geological museums in the world (Rudwick 1975: 276).

Initially Sedgwick could only offer McCoy guaranteed employment for one year but this was extended to three years so that he could complete his arrangement of the Museum's palaeontological specimens, both British and foreign. In total they collaborated on the project for nearly eight years; for the first three years McCoy worked fulltime, then part-time. In 1849 McCoy was appointed to the Foundation chair of geology and mineralogy at Queen's College Belfast. His duties included responsibilities as Curator of the Museum, but he continued to travel back to Cambridge to work on the collections during vacations. Sedgwick reported that McCoy approached his work with

enthusiasm and "almost incredible labour and perseverance" (Sedgwick, quoted in Darragh 1992: 17). To give some idea of the extent of McCoy's work, Sedgwick, quoting from the Cambridge University Commission's *Blue Book* of 1852, remarks on McCoy's work on Count Münster's fossils — just one of the collections held by the Woodwardian Museum — as follows:

> "Some notion may be formed of the greatness of his task when it is stated, that Count Münster's duplicates amount to more in number than 20,000, and that they form but a minute fraction of the great Palaeontological series Professor M'Coy has now arranged stratigraphically in the Museum" (Sedgwick 1855: vii)

Sedgwick further testified that towards the completion of the project "Professor McCoy was employed upon the Collection, not only during long hours of the day, but frequently during the late hours of the night" (Sedgwick 1855: viii). Initially released in three parts (McCoy 1851, 1852, 1855) this work on the British Palaeozoic fossils was collectively published as A Systematic Description of the British Palaeozoic Rocks and Fossils in the Geological Museum of the University of Cambridge (1855), a comprehensive and significant work in the history of palaeontology. One of McCoy's contemporaries, Professor Heinrich Bronn of Heidelberg welcomed the book as "one of the most important appearances in the literature of Palaeontology" (Fendley 1969: 134), and as Sedgwick remarked in the Introduction, "Whatever may be the merits of the following work, it is one of enormous labour."

It is clear that Sedgwick was very pleased with McCoy's contribution, describing him as "one of the very best palaeontologists in Europe". However, it was not just McCoy's important and wide-ranging contribution to systematic palaeontology, or his dedicated work in organising the collections in the Woodwardian Museum, that elicited Sedgwick's fulsome praise — he had another much more personal reason to be grateful to McCoy. For a number of years before he hired McCoy, Sedgwick had been locked in an increasingly frustrating and bitter geological dispute with his former friend and collaborator, Roderick Impey Murchison. Because of his association with Sedgwick, McCoy also, incidentally, and probably reluctantly, became involved in the debate, but nevertheless played a decisive role in its eventual resolution.

The Development of Stratigraphy in Britain

By the beginning of the 19th century in Britain it was generally accepted that the earth's rock strata were more or less in regular order as suggested by a variety of indicators such as lithology, mineralogy, morphology and organic remains. With the founding of the Geological Society of London in 1807 the organisation and order of the rock strata became a major focus for British geologists. Indeed, as a number of authors have pointed out (for example, Porter 1977: 181), most British geologists in the early to mid 19th century were stratigraphers or in some way supporting stratigraphical activities. At this time the term 'geology' became virtually synonymous with 'stratigraphy'.

Following the publication of William Smith's geological map of England and Wales in 1815 and George Bellas Greenough's improved version in 1820 considerable attention was placed by the members of the Geological Society on gathering more comprehensive and reliable geological data from all over Great Britain. Geological mapping of the rock sequences in Britain began in earnest in the early 1830s chiefly due to the work of Henry De La Beche, who was appointed as first director of the Geological Survey of Great Britain in 1835, and work accelerated in the 1840s as the number of staff members of the Survey increased.

A parallel and necessary development that accompanied the production of useful and accurate geological maps was the growing understanding that 'organic remains' or fossils were critical indicators in determining the relative age and order of the stratigraphical rock sequences. In the early years of the development of the science and art of stratigraphy, it was lithology and geological structure that were the chief criteria in the recognition of major rock units and therefore of geological time units — for example, the term 'Jurassic' was applied to strata that corresponded to the Jura limestone; similarly, 'Cretaceous' for the chalk beds, 'Carboniferous' for the Coal Measures, and so on — however it became progressively apparent that many sedimentary rock units contained recognisable and distinct fossil faunas and floras and these could often be used to unambiguously determine the order of succession and relative ages of the strata. As a result, palaeontology increasingly came to be appreciated as an essential practical tool in geological mapping.

The use of fossil organisms for the elucidation of the age and order of sedimentary rock sequences

is known as *biostratigraphy* or *stratigraphical palaeontology* and its establishment as a sub-discipline within geology was an important step in the development of a number of related fields such as historical geology, sedimentology, economic geology and evolutionary biology. Zittel (1901) provides an early authoritative account of the history of stratigraphy. Other useful references include Berry (1968) and Gohau (1990). A succinct but inclusive article on the development of the Geological Time Scale is given by Branagan (1998).

Adam Sedgwick

One of the most important early contributors to the mapping of Britain's rocks was Adam Sedgwick (1785–1873), who was elected as Woodwardian Professor of Geology at Cambridge University in 1818. Although Sedgwick must have had at least a passing interest in geology as evidenced by his attendance at a meeting of the Geological Society of London in 1816 (Speakman 1982: 56; Woodward 1907: 39) his formal training and experience in the subject were minimal prior to his election. Trained in the classics and mathematics and ordained in 1817 he was favoured for the post as Professor of Geology more for his general academic and personal qualities than for any specialised geological knowledge he may have possessed at that time. Nevertheless, from the outset he embraced his new role with keen anticipation and zeal. He became a fellow of the Geological Society of London and carried out his first geological excursion in the summer of 1818 (Rudwick 1975: 275). The following year he began a course of lectures on geology which proved to be popular, influential and enduring. This celebrated lecture series was repeated annually until 1870; a period of over fifty years.

Sedgwick soon made up for his lack of experience and expertise in geology by familiarising himself as far as he was able with all aspects of the discipline. Within a few years he was presenting and publishing noteworthy papers and also developed a reputation as a superb field geologist. He was president of the Geological Society of London from 1829 to 1831, and of the British Association when it held its first meeting at Cambridge in 1833. Perhaps reflecting his mathematical background Sedgwick is reported to have had an uncommon ability to visualize and reconstruct geological structures and sequences based on specific but limited information such as strike and dip measurements, jointing patterns, bedding plains and cleavage. He also had a capacity for translating local field observations into a broader regional context. This ability was early indicated when in 1822 he set about deciphering the dramatic and geologically complex rocks of the Lake District. It was in that year he first met William Wordsworth with whom he developed a warm friendship. They carried out many joint excursions into the Cumbrian Mountains. Sedgwick's *Letters on the Geology of the Lake District*, possibly his most well-known and widely read composition (Speakman 1982: 64), was later published along with Wordsworth's *Guide to the Lakes* in John Hudson's *Complete Guide to the Lakes* in 1842.

Sedgwick took an early interest in geological questions associated with lithology and stratigraphy. He was particularly influenced by the work of William Conybeare, one of the founders of systematic stratigraphy. In 1822, William Conybeare and William Phillips published their *Outlines of the Geology of England and Wales*, a handbook that summarised the stratigraphy of England, as it was then understood — from the recent unconsolidated sediments in eastern England to the base of the Old Red Sandstone in the west. This book helped lay down the foundations of English stratigraphical geology and influenced the direction and content of both Sedgwick's and Murchison's subsequent research.

Abraham Werner had earlier, by the 1790s, firmly established the concept of geological succession as the basis for the science of geology as it was then conceived. Werner subdivided the geological column into three principal sequences or 'formations', i.e., Primitive (or Primary), Secondary and Tertiary. He later added a fourth subdivision, the 'Transition' sequence, to denote an obscure and somewhat ambiguous series of rocks between the apparently unfossiliferous Primary rocks and the Secondary rocks which were usually layered and fossiliferous. The Primary, Secondary and Tertiary rocks in general seemed relatively straightforward and accessible for study, but the Transition rocks were somewhat of a mystery. The Transition rocks were usually layered or stratified but generally highly deformed, and even though fossils were known to be present they did not appear to be in great abundance. The opportunity for unravelling the true nature of this as yet poorly elucidated sequence beckoned for any aspiring ambitious geologist. There was the added attraction that it was then assumed that somewhere in the Transition sequence

the exact point at which life began might be discovered. Sedgwick and Murchison decided to take up the challenge by attempting to decipher the Transition rocks in southwest Britain.

Roderick Impey Murchison

Murchison, like Sedgwick, became a leading figure in nineteenth century geology (Stafford 1989), and eventually eclipsed Sedgwick in status. His earliest most important influence was William Buckland, professor of geology at Oxford University. Murchison was seven years Sedgwick's junior and actively cultivated a relationship with him; he benefited considerably from Sedgwick's geological knowledge and experience. Highly focussed and intensely ambitious, Murchison eventually outgrew his mentors to become one of the most influential scientists of modern times. He achieved this by hard work and a strategic research campaign — and also by securing membership and leadership of important scientific societies such as the Geological Society of London that he joined in 1824 and served as president from 1831 to 1834 and again from 1841 to 1843. He was a co-founder of the Royal Geographical Society and was its president for many years, enabling him to become a principle player in colonial science and exploration (see Stafford 1989). This dominance was further enhanced when he became director general of the Geological Survey of Great Britain in 1855 following the death of De la Beche. Murchison's influence eventually extended around the globe — including not only the British Empire but also Europe and North America.

Collaboration

Murchison's collaboration with Sedgwick began in the latter half of the 1820s; they conducted field trips to Scotland (1827) and the French Alps (1829) and published lengthy memoirs in the *Transactions* of the Geological Society. In 1831 they turned their attention to the relatively unknown Transition rocks of southwest England and Wales. The Transition rocks mainly consisted of thick confusing sequences of slate and the coarse dark sandstone known as greywacke. Greywacke is grey-coloured, poorly sorted sandstone ('dirty sandstone') consisting of quartz and feldspar grains and broken rock fragments mixed with substantial amounts of clay particles. Most of these Transition rocks were folded, faulted and altered.

To make sense of the Transition sequence was potentially a huge task so they decided upon a division of labour. Sedgwick would tackle the older primary and apparently lower Transition slaty rocks of North Wales. Murchison on the other hand decided on an approach from Western England into Wales from the southeast and would tackle the upper Transition sequences which were less disturbed and, as he discovered, more fossiliferous. For several field seasons they systematically devoted themselves to the task. Working cooperatively, but separately, they were soon satisfied that they were studying two different but contiguous geological 'systems'. By 1834 they felt that each had identified and interpreted the major structural, lithological and palaeontological features of their respective regions. So, in that year they spent four weeks together on their first, and what turned out to be, their only, joint field trip on the Transition rocks, in order to work out how the two systems meshed together and precisely where the common boundary might be.

Although the 1834 field trip was comparatively brief and a few issues remained unresolved, the two co-workers were confident that they had done enough work to clearly delineate two discreet geological systems and the joint boundary between them. Consequently, in 1835 Murchison designated his section as the 'Silurian' system, after an ancient British tribe that had inhabited the area. Sedgwick followed soon after with the name 'Cambrian' for the lower section after the Roman name for Wales. In August 1835 Murchison and Sedgwick presented a joint paper before the British Association for the Advancement of Science titled *On the Silurian and Cambrian Systems, exhibiting the order in which the older sedimentary strata succeed each other in England and Wales*. Both geologists were justly proud of their achievement. They were aware that their success in unravelling the structure and order of succession for the Lower Palaeozoic rocks in Britain would likely have global ramifications.

Interlude: The Fossil Plants of Devon

Even as Murchison and Sedgwick presented their findings on the Transition rocks in 1835, however, a complication had already arisen which loomed as a potential threat to their proposed classification. Just prior to their announcement of the establishment of

the Silurian and Cambrian systems, Henry De la Beche, in December 1834, reported that he had discovered fossil coal plants in Devon, supposedly of Carboniferous age, in the greywacke rocks (Rudwick 1985: 93). Sedgwick and Murchison were alarmed by De la Beche's report because it appeared to contradict their claims that the greywacke strata they themselves were studying were more ancient, and below the Carboniferous, with probably different plant types, if any at all. They felt sure that De la Beche was wrong and in 1836 they went out to investigate the area for themselves. They were able to establish that the coal bearing rocks were indeed above the greywacke and almost certainly did belong to the Carboniferous. However, the strata of rocks just below the coal bearing ones were intriguing and captured their attention because they appeared a bit different from anything else they had examined before. Because of their lithological form these rocks were initially thought to be Cambrian, but unlike Sedgwick's strata in North Wales which were relatively deficient in fossils, the rocks in Devon included many limestone beds and contained numerous fossils that had no apparent affinities with the Cambrian. Likewise, Murchison was reasonably sure they were not Silurian although there did appear to be some similarities between some elements of the two faunas. Another feature of these rocks was that the Old Red Sandstone was absent, whereas to the north, in Wales and the adjacent counties in England, it was present — in some places thousands of feet thick — and occupied a position below the Carboniferous but above the Silurian.

The controversy simmered for several years but in 1837 moved towards resolution following the suggestion by William Lonsdale — who was an expert on corals from the Carboniferous (or 'Mountain') limestone and had also worked on the Silurian corals — that in his opinion the disputed fauna was intermediate in character between the Carboniferous and the Silurian. In effect, the disputed fauna came from rocks that were apparently a marine sequence equivalent to the non-marine Old Red Sandstone in other areas of England and Scotland. At first there was some hesitation by Sedgwick and Murchison in accepting this explanation but after further study, including a field trip to Germany and Belgium in 1839, they came to the view that what they were dealing with was a distinct fauna in its own right and gave it the name 'Devonian'. This verdict was notable because it rested primarily on the fossil evidence rather than the lithology. This was the first time that priority had been given to fossils in defining a major new geological system.

Publication of The Silurian System

Murchison, in particular, was determined to defend and promote his and Sedgwick's interpretation of the Transition rocks, or at least Murchison's version of it. In his introduction to *The Silurian System* (1839: 6) Murchison indicates that he initially intended to publish his results as a memoir in the *Transactions* of the Geological Society (Thackray 1978: 63; Bassett 1991: 20). As early as 1834 arrangements were made with the London publisher John Murray for the production of a separate treatise. A prospectus was issued and subscribers were sought. It took until 1839, however, before the project could be brought to completion. The result was a massive work, possibly three times the size originally planned (Thackray 1978: 64). *The Silurian System* was one of the most significant geological publications of the nineteenth century. By any measure it was an outstanding production. It was a hefty two-volume work, 820 pages in length, with a large folding accompanying map bound separately. It was also liberally illustrated with 112 wood engravings in the text and 14 scenic plates, three of which were hand coloured. In addition, in the second volume titled "Part II. Organic Remains" there was included 31 plates of fossils plus 9 hand-coloured fold-out copper plate engravings of geological sections. The palaeontological volume was essentially an edited work with contributions from J. de C. Sowerby and John Salter (shells, including the molluscs and brachiopods), Louis Agassiz (fish), William Lonsdale (corals) and Murchison himself with Charles Stokes (trilobites). Other minor contributors included John Phillips (encrinites), W.S. Macleay (annelids), Milne Edwards ('nondescripts'), W.J. Broderip (bivalves), and C. Koenig and H.H. Beck (graptolites).

The text was comprehensive, authoritative and accessible — but most of all it was a rationale for Murchison's Silurian system and a testament to his rise to dominance in world geology and palaeontology. Murchison's Silurian system with its characteristic invertebrate fauna rapidly gained acceptance in Europe and North America. The book was dedicated to Sedgwick but in hindsight it was a dedication that probably became more of an embarrassment to Sedgwick than a tribute — particularly as Sedgwick failed to produce a similar magnum opus despite repeated promises to do so.

The publication of *The Silurian System* made public for the first time differences of interpretation in exactly where the boundary lay between the Cambrian and Silurian. Sedgwick was surprised to find that certain areas that he and Murchison had formerly agreed were Cambrian were now claimed by Murchison to be Silurian. Initial polite disagreement over these relatively minor regions eventually escalated into one of the major geological disputes of the nineteenth century — mainly because Murchison in his publications progressively annexed more and more of Sedgwick's Cambrian strata until little remained. To employ a military metaphor (which Murchison loved to do), we could say that what began as a border skirmish ended up as open warfare and a strategic grab for territory.

The Cambrian–Silurian Conflict

Privately and publicly, argument and counter-argument took place in this protracted and rather complicated debate over the next two decades. Murchison, however, steadily and inexorably gained the ascendancy in the debate. Early in his geological career Murchison was impressed by the importance and efficacy of fossils in determining the age and order of the rock strata (although in this he had to rely on the skills of palaeontologists such as Lonsdale, Phillips, Sowerby and Salter rather than on his own determinations). While he recognised that lithology was important, Murchison over the years became increasingly conscious of the potential of fossils to define uniquely and correlate different rock strata. His confidence was strengthened when he discovered that with a bit of dedicated fieldwork Silurian rocks could be found that contained a recognisable and distinct fauna. Sedgwick, by contrast, like the majority of geologists, such as Aveline, Ramsay, Selwyn and others of the Geological Survey, believed in the primacy of lithology as a basis for identifying and delimiting the stratigraphical sequence. Sedgwick viewed fossils as a secondary tool, and certainly useful when other methods are unavailable, but believed that they should not be relied upon as the primary instrument in stratigraphical analysis. In his 1831 presidential address to the Geological Society of London he pointed out:

> "Organic remains often help us to associate disconnected base lines. They also help us subdivide the successive deposits of an epoch, in areas where all other means fail; and in speculating on the former condition of the earth they are invaluable; but they can in no instance supercede the necessity of study in detail of the structure and superposition of the great mineral masses covering the surface of the globe" (Sedgwick 1831; Speakman 1982: 78).

Even though Sedgwick regularly collected fossils on his field trips he admitted that although he knew many of them "by sight" he did not always know them by name (Speakman 1982: 78). Many of the fossils he collected remained unpacked and unsorted in the Cambridge Woodwardian Museum. Sedgwick was also at a disadvantage in the debate in that he was unable to establish an unequivocal distinct fauna in the apparently less fossiliferous Cambrian rocks. Instead he emphasised the immense thickness of the Cambrian strata. But as Murchison later declared: "...was the Cambrian system ever so defined, that a competent observer going into uninvestigated country could determine whether it existed there?" (Murchison 1852: 176; Berry 1968: 87). Murchison did indeed have a point; while geologists could positively identify his characteristic Silurian fossils anywhere they occurred around the globe, the best that could be said of Sedgwick's system was that it was a local entity that may or may not have implications outside his study area in Wales. Murchison was free to claim that Sedgwick's system was merely an earlier extension of the Silurian, and he did just that. By 1842 Murchison was asserting that on the basis of the evidence gathered up until that time it now appeared that Sedgwick's Upper Cambrian fossils were identical with his own Lower Silurian fauna. Only a small section of unfossiliferous rocks remained of Sedgwick's original Cambrian.

Sedgwick argued long and hard over the ensuing years in order to save his system. He carried out more fieldwork, he examined new areas and re-examined old ones, he put forward a number of new schemes, he invented new terminology and he was even willing to drop the name Cambrian altogether; however at this stage of the dispute he made limited progress in winning converts and convincing others of the merits of his ideas. As a result of Murchison placing more and more emphasis on fossil evidence to justify his system Sedgwick was forced to take the palaeontological aspect of the work much more seriously.

In 1842 he employed a young palaeontologist, John Salter, part-time, to help process the now vast collection of fossils he had accumulated over the years. Salter also accompanied him on a number of

fieldtrips to North Wales collecting fossils in an attempt to clarify the palaeontology and possibly even discover a discreet but simpler fauna than the Silurian, although by this time Sedgwick had virtually given up any hope of finding enough distinctive species (Secord 1986: 116). Even though they discovered some new fossils, there were not enough to constitute a system distinct from the Silurian. The remainder of the fossils collected were Lower Silurian types, which by now Sedgwick had come to expect. Salter made a promising start on cataloguing the Woodwardian Museum collection but soon left for full-time employment at the Geological Survey of Great Britain. This again left Sedgwick with the need for the services of a palaeontologist. The job was offered to a grateful Frederick McCoy who was relieved to be able to remove himself from the difficult circumstances he found himself in under Thomas Oldham's supervision in Ireland. McCoy's task was to complete the work that had been started by Salter.

McCoy and Murchison's 'Caradoc Sandstone'

McCoy, like Salter before him, arrived at a critical stage in the Cambrian–Silurian debate. McCoy conscientiously applied himself to the task of processing and determining the fossils in the Woodwardian Museum but also inevitably became involved in issues related to the disagreement between Sedgwick and Murchison. It should be noted that by the time of McCoy's arrival at Cambridge in 1846 it was not just Murchison and Sedgwick who had examined the Transition strata in question. By 1841 professional geologists of the official Geological Survey of Great Britain, who had just completed mapping of the coalfields of South Wales, began mapping in the area under dispute. John Phillips, one of the Survey's palaeontologists, reported that, in the Caradoc formation which was located towards the bottom of Murchison's Upper Silurian system, there were occasional anomalies, particularly in the Malvern Hills, in which Lower Silurian fossils would be found mixed with Upper Silurian (Phillips 1848). Everyone involved in the debate, including Sedgwick, believed that the Caradoc Sandstone was a coherent set of so-called "passage beds" positioned between the Silurian and the Cambrian which therefore could feasibly contain an intermediate or a mixed fauna. McCoy, however, probably alerted by the Malvern Hills anomalies reported by Phillips (Bassett 1991: 31) began to suspect that possibly there were two different faunas involved, in deceptively conformable beds, but which appeared to be one lithological unit. Consequently McCoy, in the summer of 1852 was moved to conduct a review of the Caradoc faunas.

On examination of Caradoc fossils from a number of different localities McCoy found that they did separate out into two quite different groups — from some localities the Caradoc fossils had affinities with the Upper Silurian, from other localities the Caradoc fossils had affinities with the Lower Silurian (Murchison's Lower Silurian being roughly equivalent to Sedgwick's Cambrian). This strongly suggested the presence of a previously undetected unconformity within the Caradoc Sandstone. If McCoy was correct, then Sedgwick finally had a decisive and convincing way of splitting the Transition strata into two natural systems. Sedgwick was not willing to publicly announce these findings until he had confirmed them by examination of the Caradoc rocks in the field. In mid 1852 McCoy accompanied Sedgwick on a brief, rain-interrupted field trip which only allowed them to examine systematically the rock sections at May Hill and the Malverns, but that was enough to confirm McCoy's findings and vindicate Sedgwick's claims for a separate Cambrian system.

In November 1852 Sedgwick triumphantly presented his results in a paper to the Geological Society. Sedgwick asserted that he was able to justify subdividing the former Caradoc formation into two new groups; the upper part he named the May Hill Sandstone, the base of which Sedgwick designated as the base of the Silurian; for the lower part he retained the name Caradoc, this he designated as the top of the Cambrian. The fossil gap between the Cambrian and the Silurian on this evidence was much greater than the break between the Silurian and Devonian that Murchison had so strongly advocated; in fact, it proved to be one of the larger breaks in the whole of the fossil record. Sedgwick's explanation also correlated well with similar findings in Palaeozoic strata in central Europe and North America.

The reaction to Sedgwick's presentation by the members of the Geological Society was one of either stunned disbelief or grave scepticism. At first they could not accept that the professional geologists of the Geological Survey would not have realised or noticed that such a large geological and palaeontological divide existed between the two proposed systems. However, further work revealed that

this was indeed the case. McCoy, incidentally, had also been present at the meeting in which Sedgwick presented his findings but interestingly he was not a co-author of the paper. Edward Forbes initially believed that McCoy had "cooked" the fossil evidence in order to please Sedgwick (Secord 1986: 246). The Survey team were in an embarrassing position — in their detailed examination and mapping of the relevant strata they had not noticed any discontinuity in the rock sequence or in the fossil record (apart from Phillips' report of minor anomalies). They were forced back out in the field to re-examine critical sections and duly discovered previously unnoticed unconformities.

The Survey team tried to play down the significance of Sedgwick and McCoy's research and even suggested that they had only repeated work that had already been carried out by Phillips and others. But of course there is a huge difference in noticing and recording a variation or anomaly and in understanding its significance. Over the next few years Aveline, Salter and Ramsay of the Survey team, as well as Sedgwick and McCoy, carried out numerous field trips into Wales examining rock sections, clarifying the identity and range of key groups of fossils, and revising and redrawing critical boundaries on their geological maps. It does seem somewhat ironic that McCoy, who is sometimes disparaged for the quality and quantity of his fieldwork, happened to participate in fieldwork — although admittedly in the presence of Sedgwick, one of the most capable field geologists of his era — that led to the eventual resolution of one of the most intractable and historically significant disputes of the formative period of stratigraphical palaeontology.

Murchison, however, was not prepared to concede that he had been in error; by this time he had gained international acclaim for his work on the Silurian. Murchison evidently felt that the stratigraphical model that he had so assiduously and so laboriously constructed, now almost self-evident, would be in danger of being ruined, along with his scientific reputation, if he yielded to Sedgwick's revised Cambrian. Independently wealthy, Murchison was also in a powerful position institutionally, and even more so after he became Director of the Geological Survey on the death of De la Beche in 1855. In contrast to Sedgwick, his career and reputation had gone from strength to strength. He was knighted in 1846. In 1841, on his second expedition to Russia, he succeeded in making another important contribution to world geology. In the district of Perm located on the Western flank of the Ural Mountains he identified a thick, relatively undisturbed sequence of rocks overlying the Carboniferous that he designated the 'Permian'; another significant geological system was thus identified and defined. In 1845 he published a second major work *Geology of Russia in Europe and the Ural Mountains* (co-authored with de Verneuil and von Keyserling).

Sedgwick, sadly, was never able to complete his proposed opus on the Transition strata intended as a companion volume to Conybeare and Phillips' *Outlines*. Sedgwick became increasingly embittered at Murchison's unwillingness to recant, and isolated himself from the Geological Society. This played into Murchison's hands and there were suggestions by members of the Geological Survey that Sedgwick was a zealot and probably going senile or insane.

McCoy's reputation, too, suffered by association. Edward Forbes satirically depicted Sedgwick as Don Quixote, and McCoy as Sancho Panza (Secord 1986: 267). While this representation of Sedgwick displays a certain respect for his moral integrity, it strongly suggests he is fighting for a hopeless cause and perhaps a little obsessed and a little mad. McCoy, by implication, is portrayed as a blind, loyal subordinate who would do anything to please his master. One partial consequence of the factionalism in this dispute and the defence of entrenched positions is that McCoy has never received due recognition for his contribution to resolution of the debate or for his wider contributions to palaeontology and biostratigraphy. Murchison used his influence as head of the Geological Survey, and as a member of the Geological Society and other organisations, to control the terms and direction of the debate and to prevent any changes in nomenclature or in the details of the standard geological maps of which he did not approve. For ambitious younger geologists and palaeontologists jobs were scarce and Murchison's patronage and approval were essential if they were to have any real chance of obtaining a desired position or gaining promotion. In this respect McCoy was no exception.

As the debate dragged on McCoy tried to distance himself publicly somewhat from Sedgwick although privately he remained a steadfast supporter. He tried to indicate to Murchison that he was 'just doing his job' objectively without prejudice or personal preference. In a telling letter to Murchison in June 1852, McCoy disingenuously declared his impartiality in the debate at the very time he was

urging Sedgwick to re-examine and reassess the Caradoc Sandstone sections:

> "I hope that you and Professor Sedgwick have long before this settled to your mutual satisfaction the bounds of your grounds? I feared I should have come in for some knocks, although I have never intruded myself into the discussion but confined myself to identifying the fossils to the best of my ability and registering them faithfully. A smack from you would probably ruin my prospects, and I think undesirably — but I believe you spare the weak in as marked a manner as you grapple with the strong." (McCoy to Murchison, 12 June 1852, in Craig 1971: 494; Secord 1986: 271)

Murchison was aware that McCoy was an able and self-assured palaeontologist, and even a dangerous one while he was working in league with Sedgwick. Hence, it suited Murchison to give McCoy a favourable reference for the Foundation chair of Natural Science at the newly established University of Melbourne. Whether Murchison's testimonial was given because he genuinely believed that McCoy deserved the position based on merit, or simply because he wanted to get him out of the way, or both, it is difficult to say, but it did have the dual effect of removing support for and further isolating Sedgwick and removing McCoy from the mainstream activities in Great Britain. In 1854 McCoy applied for the Melbourne chair and was successful against a strong field of candidates. In early October of that year he set sail from England for Australia in the clipper *Champion of the Seas* (Wilkinson 1996: 54) and disembarked in Melbourne where he would spend most of the rest of his working life.

In the years that followed, local and international support for the Cambrian grew, but Murchison died in 1871 still opposing any change in nomenclature. The debate was effectively settled with the inclusion of the Ordovician system by Lapworth in 1879 which was inserted as a kind of no-man's land between the Cambrian and Silurian systems although, remarkably, even though the case for a new system based on the fossil evidence was compelling it took until 1960 for the Ordovician to gain full international approval (Secord 1986: 310). The new Ordovician encompassed Sedgwick's Upper Cambrian and Murchison's Lower Silurian, but one can speculate with confidence that both protagonists probably would not have been at all enamoured with Lapworth's partial appropriation of their respective geological territories.

McCoy in Melbourne

When McCoy arrived in the Colony of Victoria in December 1854 as one of the first four professors at the University of Melbourne he was still only in his early thirties and already an accomplished palaeontologist. Not only was he thoroughly familiar with Irish and British fossils but had also had some experience with Australian material. In Great Britain he had worked on Australian fossils collected by the Reverend W.B. Clarke and sent to Sedgwick at Cambridge. In 1847, he published a paper based on this work titled "On the fossil botany and zoology of the rocks associated with the coal of Australia" in the *Annals and Magazine of Natural History*. This familiarity with Australian fossils was possibly one of the factors that enticed him into immigrating to Australia. Soon after his arrival in Victoria as Professor of Natural Science, McCoy set about grappling with issues connected with the local palaeontology and stratigraphy and (with Murchison's endorsement) was appointed Palaeontologist to the Geological Survey of Victoria in 1856. He moved quickly in taking over the Colony's fledgling natural history museum and despite some spirited public opposition moved it from its city location to the grounds of the University of Melbourne (Pescott 1954; Wilkinson 1996; Rasmussen 2001). Overcoming many obstacles, including numerous bureaucratic disagreements, political disputes, and ongoing funding shortfalls, he resolutely proceeded to build the National Museum into a world-class institution. He was appointed Director in 1858.

Australian Stratigraphy Before 1850

Prior to McCoy's arrival in Australia in 1854 there had been no resident skilled palaeontologist. Geological observations had been carried out by many of the early explorers and naturalists such as Mitchell, Leichhardt, Strzelecki, Oxley, Grey, Cunningham, King, Gregory, Stokes, Sturt, Eyre, Darwin, Dana, Jukes, Clarke, Stutchbury and others. Some of these geological observations were of a high standard, e.g., those of Leichhardt (1847) and Strzelecki (1845); other observations had been more cursory and less reliable but nevertheless still interesting and suggestive. Visitors from overseas such as Darwin and Jukes made valuable observations and determinations, as did James Dana from North America who collected fossils and worked on them.

Fig. 2. Photograph of Frederick McCoy, c. 1870, seated. Johnstone, O'Shannessy & Co., photographers. H29553. La Trobe Picture Collection, State Library of Victoria.

Generally though, in order to obtain reliable fossil determinations, specimens had to be sent overseas to Britain and Europe for identification by expert palaeontologists such as Lonsdale, Morris, Owen, Sowerby, de Verneuil, de Koninck, d'Orbigny and, indeed, McCoy himself. The first steps in elucidating the stratigraphy of Australian rocks were being made but much of this work remained unconfirmed and uncertain.

Although it was well established that in a mineralogical and lithological sense rocks all over the planet were broadly comparable the old Wernerian notion of universal formations had been superseded. Grand global geological theories were now being treated with suspicion, and in keeping with prevailing scientific method most geologists adopted, or at least, subscribed to, a strict empirical and inductive approach. There were conflicting notions of what the geological evidence signified and how the stratigraphy of Australia fitted into the overall picture. In an interesting paper published in the *Tasmanian Journal of Natural Science* in 1843, the English geologist Joseph Beete Jukes, who spent from 1842 to 1846 in Australia waters as naturalist on board H.M.S. *Fly*, cautioned against drawing any hasty and premature conclusions when dealing with non-European strata:

> "The European geologist, in approaching distant countries, must loose his hold of much of his previously acquired knowledge; dismiss from his mind all the arbitrary and minute divisions to which he has been hitherto accustomed, and hold them at bay until he see whether or not they be applicable to the things he is now studying. He must at once fall back on the general principles on which all geological classification ought to be founded; and, guided solely by these, separate the rocks he meets with into those portions and divisions only which naturally belong to them. When each large portion of the globe shall have been examined, and its constituent portions classified and arranged in this manner, geologists will be able to compare them one with the other, to establish well-defined bases, and make out the corresponding terms in each series, and tabulate the whole according to their united result." (Jukes 1843: 4–5)

In 1850 Jukes published a small monograph *A Sketch of the Physical Structure of Australia, so far as it is at present known* in which he summarised his conclusions concerning the geology of Australia based on his own first-hand observations combined with information from the published reports and books of other explorers and naturalists, some of whom he met personally such as Mitchell, Strzelecki and Sturt. This memoir was the first brief but comprehensive summary of Australian stratigraphy and was a valuable synopsis of isolated geological observations from a variety of sources. Included in his book was a coloured geological map of Australia which attempted to encompass the continent as a whole, although of necessity much of the unexplored interior remained a blank. Although he discussed the Australian palaeozoic rocks in general, Jukes was reluctant to subdivide them any further based on the then current knowledge:

> "... I should for the present hold that the rocks of Australia now under consideration simply as palaeozoic, and only assert that their age was included within that of our Silurian, Devonian, and Carboniferous periods." (Jukes 1850: 22)

Jukes attempted to locate Australian geology in a broader international context and tentatively noted many similarities between European and Australian geology and geomorphology but was also intrigued by the apparent differences. He was impressed by the "simplicity and uniformity of the geology when looked at on the great scale" (Jukes 1850: 79). As Vallance (1975: 22) explains, the early Australian explorers "found a continent whose physical features differed utterly from those of Europe; Instead of a great median mountain axis in Australia there were low arid plains, the mountains of Australia followed the east coast." Jukes (1850: 1) conceded that it was difficult for geologists "accustomed only to the full, varied, and complex structure of Europe" to come to terms with the very different situation in Australia. To an external observer Australian geology appeared deceptively uncomplicated. He observed that,

> "Australia especially seems the very land of uniformity and monotony, the same dull and sombre vegetation, the same marsupial type of animals, spread over the whole land from the gloomy capes of the south coast of Tasmania, and the stormy Lecuwin, to the cloudless and burning skies of Torres Straits and Port Essington." (Jukes 1850: 2)

The Missing Mesozoic

Jukes, like many other observers before and after him, was impressed by the idea that Australia was a

land of anomalies. The anomalous geology and geomorphology seemingly matched the similarly anomalous flora and fauna. According to Jukes, a number of geologists had,

> "been struck with the entire absence of all "secondary" formations in Australia, and with analogies between the fossil flora and fauna of our European oolitic series, and those now found living in Australia and Australian seas."

Ever since the time of Lamarck and the discovery of the bivalve *Trigonia*, found alive in Australian waters but extinct in Europe since the Mesozoic, and of various marsupials and plants which were long since extinct in Europe, there was a popular notion that Australia was 'the land that time forgot'. The rocks, the animals, the plants and even the indigenous human population were all, in comparison with Europe, very ancient. Jukes (1850: 80) noted the "total absence of any rocks of an age intermediate between the palaeozoic and tertiary, so far as is at present known or appears probable". Further on (Jukes 1850: 89) he reiterated the same point, stating: "Above the palaeozoic series there is an absolute gap, a total deficiency of all other stratified rocks, whatsoever..." except for a much more recent tertiary formation, and speculated (p. 90) that,

> "We have therefore two reasons; namely, the absence of marine formations of the oolitic age, and the possible descent of some of the animals and plants from those that lived at that period; for supposing that after the deposition of palaeozoic rocks, what is now Australia was raised into dry land, and that some portion or portions of it at all events have ever since remained above the level of the sea."

This would account for the missing Mesozoic in Australia and the preservation of organic forms which long ago had become extinct in Europe.

Jukes became a highly respected geologist in Great Britain and his views carried considerable weight. On his return to England from Australia he joined the Geological Survey of Great Britain and proved himself to be a talented field geologist working in North Wales and South Staffordshire alongside other staff members such as Andrew Ramsay, William Aveline, Alfred Selwyn and palaeontologist John Salter. In 1850 he was appointed as Director of the Geological Survey of Ireland where he served with distinction until his premature death in 1869. He wrote many papers and a number of text books which presented his views to other geologists, students and the general public.

Selwyn, McCoy and the Geological Survey of Victoria

In 1852, following the discovery of gold the previous year, and two years before McCoy's arrival, the Victorian government established a Geological Survey. The Colony was extremely fortunate in gaining the services of Alfred Selwyn as Government Geologist and later Director of the Geological Survey. It would be difficult to imagine a more appropriate choice. Prior to his appointment Selwyn had considerable experience mapping the palaeozoic rocks of North Wales which were apparently a direct analogue of the gold bearing slates of Victoria. Selwyn's appointment (1852–1869) marked the commencement of systematic geological mapping in Australia. Selwyn and his staff surveyed large tracts of the Victorian countryside and after his arrival McCoy did the palaeontological determinations necessary to determine the relative ages of the strata.

It was a highly productive collaboration. Between them Selwyn and McCoy determined the line of demarcation between the Upper Silurian (now the Silurian proper) and the Lower Silurian (now the Ordovician and Cambrian) and then steadily worked their way up the geological column. Selwyn having worked at the Geological Survey of Great Britain preferred Murchison's terminology of 'Lower Silurian' for the lower strata while McCoy having been a protégé of Sedgwick preferred to use the term 'Cambrian'. Ralph Tate (1894: 490) who a gave a paper titled 'Century of Geological Progress' for his presidential address for the fifth meeting of ANZAAS in Adelaide in 1893 remarked on this milestone in Australian geology, as follows:

> "Up to 1853 the geology of Victoria was almost a blank. What little was then known of it was due to Mitchell, Strzelecki, and Jukes, but that little was for the most part either misread, or too indefinite to be available in the future. Thanks to the ability and zeal of Mr. Selwyn and the members of his staff, aided by the palaeontological determinations of Professor McCoy, the geological structure of Victoria was rapidly unfolded, and large tracts of country were geologically surveyed in detail...."

Further on in his address, under the subheading 'Summary of Discoveries and Original Researches', Tate continued:

> "1858. Selwyn (Quart. Journ. Geol. Soc., vol. xiv., p. 533) drew the line of demarcation between the auriferous graptolite slates [Ordovi-

> eian and Cambrian] and Upper Silurian [Silurian], which McCoy had shown to have faunas characteristic of the corresponding series in Europe, and thus established the fact of the specific identity of the two faunas over the whole world."

McCoy and the Global Geological Column

In 1861 McCoy published in the Victorian Exhibition Catalogue the first summary of the zoology and palaeontology of Victoria (McCoy 1861). This paper was reprinted in 1862 in the *Annals and Magazine of Natural History*. In the paper McCoy argued that based on palaeontological evidence the geological column in Australia in general conformed to that of Great Britain, Europe and North America. For the first time it was could be stated unequivocally that the rock sequences in the Southern Hemisphere, despite some provincialism, correlated well with those of the Northern Hemisphere. In other words, the geological column as deciphered in Great Britain was almost certainly a global phenomenon. This relationship held especially for the Lower Palaeozoic but McCoy believed it was generally true for the whole geological column.

McCoy declared that "... from the great quantity of fossils which I have lately examined as Palaeontologist to the Geological Survey of Victoria; and from evidence of this kind I can offer a sketch of the ancient successive changes of organic life in this country" (McCoy 1861: 160). He proceeded to discuss each of the major geological periods in turn. Beginning with the [Lower] Palaeozoic he asserted that:

> The Azoic [Precambrian] rocks, I can now state, were succeeded in Victoria, exactly as in Wales, Sweden, North America, and other parts of the world in the northern hemisphere, by a series of rocks enclosing fossil remains of the well-known genera and even specific types of animal life characterizing those most ancient fossiliferous strata termed Lower Silurian by Sir R. Murchison, and Cambrian by Professor Sedgwick (McCoy 1861: 160).

McCoy then went on to discuss further correspondences between Australian biostratigraphy and Northern Hemisphere biostratigraphy for the rest of the geological column, i.e., the Upper Palaeozoic, Mesozoic, Tertiary and Recent periods. McCoy demonstrated striking global similarities in the fossil record across much of the geological column. In doing this, however, McCoy overstated the similarities, particularly for the upper part of the column, and it was probably this conviction that prevented him appreciating important differences which later led to the development of the concept of Gondwana, the great southern supercontinent.

At the time of the 1861 publication McCoy had already confirmed presence of the Jurassic (or "Oolitic") based on marine fossils from Queensland in 1861 and on the flora of the Bellarine and Cape Patterson coal beds of Victoria in 1860, but evidence for the Cretaceous period had not been positively confirmed in Australia. However, in 1865 McCoy was able "... to announce for the first time with certainty the existence of the Cretaceous formations in Australia." (McCoy 1865: 333) based on fossils sent to him from Queensland that included bivalves, ammonites and ichthyosaur vertebrae. Similarly, although fossils from the Devonian period in Australia had been earlier identified by Stutchbury for example, there was some doubt about the validity of this interpretation. In an essay prepared for the 1866–67 Melbourne Intercolonial Exhibition (McCoy 1867a) and reprinted in the *Annals and Magazine of Natural History* in 1867 he claimed that he had definitely confirmed the presence of the Devonian in Australia based on marine fossils from Buchan in Gippsland. McCoy declared:

> "It is with great pleasure I announce the fact of my having been able satisfactorily to determine the existence of this formation also in Australia, the limestone of Buchan in Gippsland containing characteristic corals, Placodermatous fish, and abundance of the *Spirifera laevicostata*, perfectly identical with specimens from the European Devonian Limestones of the Eifel" (McCoy 1867a: 327 (21); 1867b: 198).

For McCoy, the confirmation of these formations filled in the remaining major gaps in the geological record for Australia and demonstrated that there was an almost complete correspondence between northern hemisphere and southern hemisphere stratigraphy.

A shortened version of this paper was also made available for a North American audience and published in *The American Journal of Science and Arts* edited by Benjamin Silliman and James Dana (McCoy 1867e: 279–282). In this version, as in the original paper, when discussing the Cambrian he reiterated: "... we have in these formations the most extraordinary proof of the unexpected fact which I announced on a former occasion, that there was in the Cambrian or Lower Silurian period a nearly

complete specific uniformity of the marine faunas, not only over the whole northern hemisphere, but across the tropics, extending to this remote temperate latitude of the southern hemisphere" (McCoy 1867e: 280).

In his conclusion to the above papers McCoy reminded the reader that he had been instrumental in contributing to the solution of the Cambrian–Silurian debate and that exactly the same geological situation prevailed in Australia as it did in Great Britain. McCoy concluded:

> "I can scarcely close ... without drawing attention to the curious confirmation offered in Victorian geology of the view of Professor Sedgwick and myself, that there was a real systematic line of division between the Upper Silurian and the Cambrian and Lower Silurian, at the base of the Mayhill Sandstone and over the Caradoc Sandstone — the Mayhill Sandstone, which we first defined and demonstrated to have Upper-Silurian fossils only, and the true Caradoc Sandstone full exclusively of Lower-Silurian or Cambrian types, — the previous confusion between these two sandstones, from the erroneous mingling of their fossils in collections, having given Sir Roderick Murchison the erroneous impression that his Upper and Lower Silurian groups of fossils ... could not be separated palaeontologically....The Mayhill Sandstone was one of the first formations I recognized, on landing near Melbourne, with the usual Upper-Silurian fossils; and it is now found here, as in Wales, to be slightly unconformable to the Cambrian or Lower Silurian, forming the obvious base of the former and totally distinct [in fossils] from the latter" (McCoy 1867a: 330 (24); 1867b: 201–202; 1867c: 282).

Of course it should be acknowledged that McCoy's claims for the correlation of the Australian stratigraphy with Northern Hemisphere stratigraphy were based on not only his own work but also built on the earlier work of other geologists (e.g., see Vallance 1975; Branagan 1998). Nevertheless, it was McCoy who was the first to publish a synthesis and indicate that he was the first to fully grasp the broader implications of the local geology, palaeontology and stratigraphy and place it in a global context. Few people could have been better prepared than McCoy to appreciate the Australian stratigraphy and be able to relate it back to the British and European and American situation. He had made a significant contribution to systematically sorting, naming and describing the Palaeozoic fossils of Ireland and Britain, and had played a key role in the debate between Adam Sedgwick and Roderick Murchison on where to draw the boundary between the Cambrian and Silurian periods. At the time of his arrival in Australia he was one of the world's most experienced palaeontologists, and as Adam Sedgwick's assistant, he had played a subordinate but

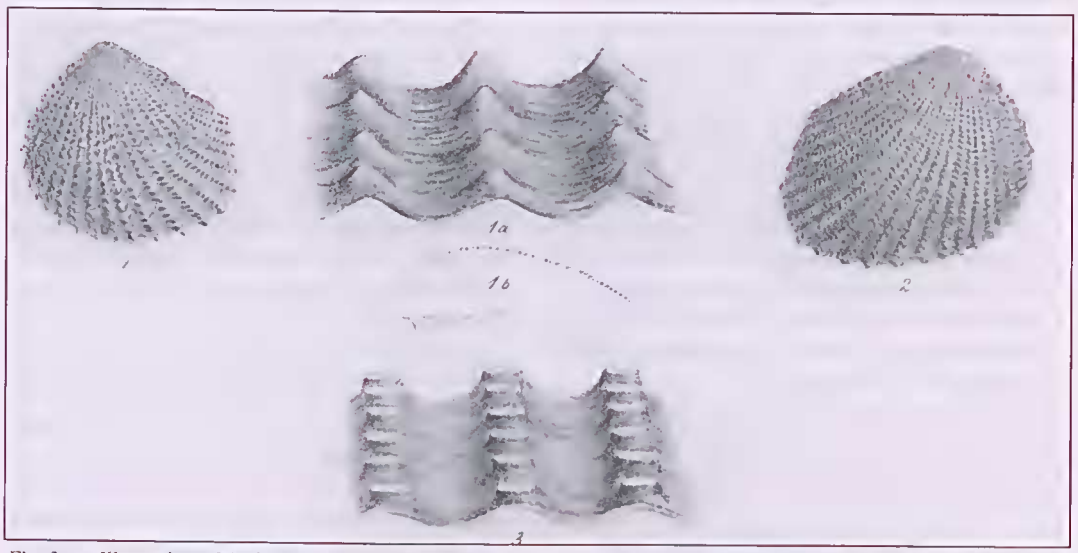

Fig. 3. Illustration of the bivalve *Trigonia acuticostata* McCoy [now *Neotrigonia acuticostata*] comparing it to the previously known *Trigonia Lamarcki* showing the acute ribs and tubercles of *T acuticostata* in contrast to the board flattened ribs and tubercles of *T. Lamarcki*. From McCoy's *Prodromus of the Palaeontology of Victoria, Decade 2* (1875: pl. XIX).

important role in critically examining fossil evidence and relating it to the structure and lithology of a geological formation or region.

There was another factor in McCoy's readiness to fit Australian geology into a larger framework. He was attempting to defend a 'progressionist' but non-evolutionary view of the world. McCoy's geological view of the earth, like his mentor Adam Sedgwick's, was more compatible with classical Cuverian catastrophism than with Lyellian uniformitarianism. McCoy was staunchly anti-Darwinian and rigidly believed in successive progressive "creations"; for example, in the 1862 paper when he speaks of the change from the Mesozoic to the Tertiary, he states:

> "... we find that here, as in Europe, the greater part of the country sank under the sea during the Tertiary period, and every trace of the previous creations of plants and animals was destroyed and replaced by a totally different new set, both of plants and animals, more nearly related to those now occupying the land and sea of the country" (McCoy 1862: 144).

McCoy viewed these postulated successive creations in global terms.

One of the main motivations for publishing his findings on the Australian stratigraphy, as revealed by McCoy in the introduction to the 1862 paper, was to counter the argument (advanced by alleged "transmutationists" and "materialists" such as T.H. Huxley and others) that evolution occurred at highly variable rates in different regions of the globe and that Australia was, in essence, an evolutionary backwater. This was another consequence of the view that had gained credence since the time of Lamarck with the discovery of the bivalve *Trigonia* (Fig. 4) and the brachiopod *Magellania* in Australian waters and of various marsupials and plants which had become extinct in Europe. By demonstrating the universality of the geological column, and that the Southern Hemisphere, despite some provincialism, correlated geologically and biologically with the rest of the world, McCoy was attempting to demolish that argument, which, in fact, he effectively did. Unfortunately for McCoy the tide of scientific opinion was by now clearly running against progressionist ideas and his induction did little to change that. Indeed, by confirming the universality of the geological column he only helped prepare the way for a strict Lyellian uniformitarianism and thus the acceptance of gradual transmutation or evolution of organic species.

McCoy identified and described several new species of *Trigonia*. *Trigonia* was previously known only from Mesozoic formations — and in the living state in Australian waters — but was unknown in the Tertiary. McCoy was pleased to declare that he had filled that particular gap in the fossil record. In his *Prodromus of the Palaeontology of Victoria, Decade 2* (1875: 21) he wrote,

> "Being enabled to announce the discovery of three distinct species of *Trigonia* from the Pliocene and Miocene Tertiaries near Melbourne clears away this supposed exception to a general Palaeontological law, and cannot fail to be welcome, not only to geologists generally, but to the biologists engaged with the large question of the succession of life on our globe."

CONCLUSION

It is clear that Frederick McCoy made a seminal contribution towards deciphering Australian stratigraphy based on his northern hemisphere experience, and especially the key role he played in the Cambrian/Silurian debate between Adam Sedgwick and Roderick Murchison. He was the first to unambiguously and definitively demonstrate that the Australian geology and stratigraphy correlated fundamentally with that of the northern hemisphere contrary to the standard European view of the time. Debate has continued until the present day on just how complete the correlations actually are. It appears that McCoy's achievements were largely underrated by the British establishment in his day, and his critical contribution has gone almost entirely unnoticed and unacknowledged by modern historians. McCoy certainly received criticism on aspects of his work by some of his contemporaries and became embroiled in a number of controversies both locally in Australia and overseas in England and Ireland. Some of this condemnation has undoubtedly contributed towards a lack of appreciation of his more positive contributions.

Perhaps another reason McCoy's achievement is not more appreciated today is because the global geological column is now taken for granted. The realization that the Southern Hemisphere was, in general terms, geologically compatible with Europe and North America was an important confirmation of the universality of geological phenomena. McCoy's anti-evolutionary stance, which he shared with many of his contemporaries including Sedgwick and Murchison, is a further reason that his scientific achievements have not been widely

appreciated. As Rupke (1983) notes many of these pre-Darwinian and anti-Darwinian scientific contributors have been either harshly dealt with by historians, or dismissed and ignored.

Because of his extensive commitments as Director of the National Museum, Professor of Natural Science at the University of Melbourne, and numerous other duties such as descriptive zoological work, McCoy never approached the prodigious output that he achieved in Great Britain in his Australian palaeontological work. Funding difficulties, bureaucratic arguments and political complications also contributed to delays in publication. Work on his *Prodromus of the Palaeontology of Victoria*, published serially between 1874 and 1882, was actually started in 1858 — the series remained unfinished with the seventh issue or 'decade'. His *Prodromus of the Zoology of Victoria* was published in twenty decades between 1878 and 1890.

The breadth of McCoy's contributions to palaeontology and modern zoology, his scientific, philosophical and theological activities aimed at the public, and his administration of public institutions and societies, have made McCoy a difficult individual to grapple with. This difficulty should not blind us to the fact that in his day he was an eminent authority and made lasting contributions not only locally but to world science generally. He was one of the pioneering figures of international palaeontology and biostratigraphy and until the arrival on the local scene of Ralph Tate and Robert Etheridge, Jnr. (Vallance 1978: 247) he was Australia's leading palaeontologist and arguably in his mature years "the acknowledged chief of the scientific world of Australasia" (Anon. 1899: 283).

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